

# Flood Risk Management Through Digital Transformation in Connection with Smart Urban Development Management: A Case of Lao Cai City of Vietnam

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## Abstract

This paper develops an approach of smart city and smart urban governance by providing ideas for using digital transformation as a tool for flood risk management and how they are translated into practice. Smart tools can only be applied if there are sufficient data provided. Therefore, real-time data and updated data collection are vital. The information is important but the more important part is the exchange data procedure or information sharing. Co-operation and participation among stakeholders in providing and sharing information can create a foundation for a smart city. The case study of Lao Cai city of Vietnam shows that digital transformation and data sharing among departments act as decision-support sources for leaders while promoting the interests of the community and professionals in urban development direction. The study suggests that instead of waiting for a synchronous system to be built in a unified standard, all levels of government in every sector need to share their data for step-by-step smarter management.

## 1. Introduction

UN Department of Economic and Social Affairs [1] estimated in 2018 that 55.3% of people are in urban settlements globally and forecasted that 60% of the world population will live in urban areas by 2030. To implement Sustainable Development Goal 11 of the Agenda for Sustainable Development, it is necessary to make cities safe and resilient, including mitigation and adaptation to climate change, in line with the 2015-2030 Framework for Disaster Risk Reduction (DRR). Digital transformation, smart governance, and smart city can and should play important roles in DRR as they help cities' governments and people prepare for and mitigate the impact of disasters. Moreover, the indicator 11.3.2 calls for the active, direct regular and democratic participation of civil society and stakeholders in urban planning and management for the sustainable urbanization of human settlement. Therefore, the co-operation among stakeholders together with digital transformation in DRR can become crucial for sustainable urban environment development. This study examines digital transformation from the standpoint of disaster risk reduction in urban management, along with the case of the application of digital

data sharing in Lao Cai city of Vietnam in an urban flood prevention system which acts as a planning decision-making supporting tools for municipal leaders.

## 2. Digital Transformation and Urban Management in Smart Cities

The past two years (2020 and 2021) have been important years for cities around the world. The COVID-19 pandemic has had profound effects on citizen lives in our cities, and municipal governments need to react quickly to protect people's lives and find the best ways to cope with the long-term effects of the pandemic. Along with the trend of smart city development, the impact of the COVID-19 pandemic has made urban people familiar with the remote working method, the urban government also has increased the process of transition to e-government. In addition to the global trend of smart cities creation that includes smart and sustainable buildings and infrastructure, intelligent mobility, cyber-security, and city operation through AI, and smart health, there are other trends of creating cities with green planning of public spaces, 15-minute approach, mass participation, circular economy, and digital innovation [2]. The strategic approach to digital transformation and digital innovation has been adopted in more cities as more people choose to work remotely. Moreover, lessons learned have shown that, especially after the COVID-19 pandemic, for disaster-affected areas, fast data sharing is an important part of disaster mitigation. This can be done more efficiently and effectively with modern technologies through the internet or a shared database. Since disasters often happen quickly, the more promptly information is shared, the more likely it is that appropriate and successful mitigation measures will be taken [3]. Digital transformation and data exchange or data sharing is one of the 8 factors related to smart city governance that Chourabi [4] has mentioned. These factors include "Co-operation", "Leadership", "Participation", "Communication", "Data exchange and open data platform", "Service and application integration", "Accountability", and "Transparency".

Urban management in smart manners can contribute to smart urban governance [16]. As Gil-Garcia [5] pointed out in 2012, smart governance is "at a higher level of transformation because it requires internal organizational restructuring of the government". In this form, it is not only the form of e-government but it needs "sophisticated information technologies to connect and integrate information, processes, organizations, and physical infrastructure to better serve residents and communities". Failure examples of technology bias smart cities have shown the importance of information transparency, leadership, co-operation, and participation in creating smart cities.

According to Harrison and Donnelly [6], the foundation of smart cities comes from urban information model which includes five groups of information layers namely (1) Natural group; (2) Infrastructure group; (3) resources group; (4) service group and (5) social system group (Fig. 1). The idea of this theory is to make the invisible visible. That idea requires collaboration among stakeholders and participation in the process of urban governance rather than relying on information technology.

Although the idea of "smart city" is widely used and accepted, the smart city approach may vary greatly [7]. One of the widely used concepts of smart cities is that defined by experts who considered smart cities as urbanized areas that take advantage of communication, data exchange, and information technologies for a better quality of their inhabitants' life [8]. With this approach, information and technology play the main role in creating a smart city. According to Chourabi [4], other definitions of a smart city do not focus on the ICT as the pivotal role but consider the use of ICT to fulfill the citizens' needs smartly. The wide-spreading debate of e-services is one of the important elements of a smart city [9]. Besides, Caragliu and Nijkamp [10], stressed that a city is governed in smart manner when investing in human and social capital along with taking advantage of ICT-based infrastructure to ensure inhabitants' high quality of life through participatory government to wisely use natural resources.

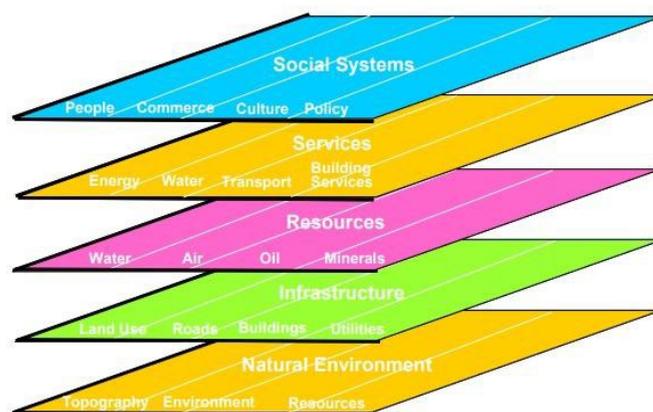


Fig. 1 Group of two-dimensional layers in urban information model [6]

However, one of the advantages of information technology is that it enables municipal governments to make decisions based on updated real-time data through digitalization. Co-operation and participation among stakeholders in providing information following [6] model can create a foundation for a smart city. Smart governance needs effective co-operation and efficient leadership that create rigid foundation for data exchange, communication, and participation and therefore, it creates accountability and transparency.

Smart city can be built on three levels. The lowest level is for the smart cities which are at the embryonic stage. In this level, smart tools are applied to solve situations. Smart tools can only be applied if it has enough database. Therefore, real-time data and updated data collection are vital. The information is important but the more important part is the exchange data procedure or information sharing. Smart governance, according to Tapscott and Agnew [11], is the broad implementation of a more community-based governing model with improved connection made possible by new technology. The basis for ensuring that information reaches municipal officials is the active involvement of citizens and professional specialists in conjunction with the IT system, as long as their contributions are openly reviewed and provided with feedback.

### 3. Materials and Methods

In order to obtain a comprehensive understanding of the trends as well as the practices of digital transformation toward smart urban development management in Vietnam, a systematic and comprehensive review of existing literature was conducted. In Vietnam, there is a large amount of related data which is not systematically collected and it is available at the provincial level but not at the city level. Moreover, some data is considered as the asset of the information provider and therefore, it is not easy to assess. In this research, the qualitative approach is applied to understand what those interpretations are at a particular point in time and in a particular context [12]. According to Flick [13], qualitative research is suitable for the study of social relations and Patton [14] also supported that qualitative research helps to understand situations in the uniqueness as part of a particular context and the interaction within.

Given that the aim of this research is to explore the situation of flood risk management through a digital transformation approach in a city of Vietnam with an orientation to smart urban development, qualitative research is chosen as a suitable method for conducting the research. Using Chourabi [4] approach, the assessment of the level of smart urban development in connection with flood risk management at the city level will be determined by the set of parameters described in Table 1. There are eight parameters namely (1) "Co-operation"; (2) "Leadership"; (3) "Participation"; (4) "Communication"; (5) "Data exchange and open data platform"; (6) "Service and application integration"; (7) "Accountability" and (8) "Transparency". The value for each criterion is ranged from 0 to 1 in accordance with the level that is met by each parameter. The maximum value is 8 points when all the parameters' criteria are fulfilled with a high level or good practice.

**Table 1** Assessment parameters for flood risk management using smart urban development approach

Parameters criteria	Low	Medium	High
	(poor)	(average)	(good)
	0	0.5	1
Co-operation	Low and ineffective co-operation in flood risk management	Moderate and sufficient effective of co-operation in flood risk management	More than adequate and stable level of co-operation in flood risk management
Leadership	Low and ineffective leadership in support of risk management using a smart development approach	Moderate and not always effective level of leadership in support of risk management using a smart development approach	Clear and effective leadership in support of risk management using smart development approach
Participation	Low level of participation and limited actors participate	Adequate actors participate and the level of participation is consult	Most of the actors participate and the level of participation is co-production
Communication	Limited communication channels with the related bodies are established	Sufficient communication channels with the	Adequate communication channels with the

Parameters criteria	Low (poor) 0	Medium (average) 0.5	High (good) 1
		related bodies are established	related bodies are established
Data exchange and open data platform	Data resources are available but the exchange is limited	Data resources are available, most of them are exchanged and opened partially	Data resources are available and most of them are exchanged and opened
Service and application integration	Some services and applications have been integrated with limited satisfaction from users	Major services and applications have been integrated with sufficient satisfaction from users	Most services and applications have been integrated with more than adequate satisfaction from users
Accountability	Limited responsibility for the actions in support of risk management using a smart development approach	Moderate morale of responsibility for the actions in support of risk management using a smart development approach	High morale of responsibility for the actions in support of risk management using a smart development approach
Transparency	Limited level of transparency in procedures and information exchange	Sufficient level of transparency in procedures and information exchange	Clear procedures and more than adequate level of information exchange

The data from statistics at the provincial level as well as assessment in Lao Cai and Hue city were synthesized to identify the situation and compared with the assessment of the pilot application to define the trends and propose a possible necessary measure for smart urban sustainable development.

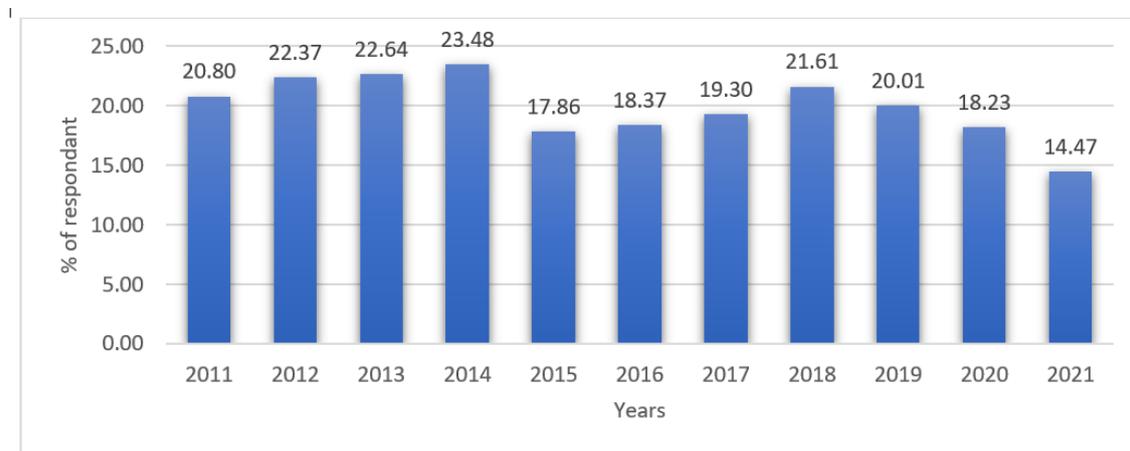
#### 4. Information Accessibility and Digital Transformation in Vietnam

In Vietnam, the idea of creating smart cities has come since the 2000s. However, in the period 2000-2010, smart city projects were locally developed and mainly IT-based and marketing-oriented. The technology-focused approach of developing smart cities in Vietnam still dominates the idea from top leaders of government. The Decision 950/QĐ-TTg dated August 01<sup>st</sup> 2018 signed by the Vietnam Prime Minister approving the scheme for the development of smart sustainable cities in Vietnam in the 2018 – 2025 period with orientations by 2030 mainly focusing on the application of ICT in different economic sectors. In the Smart City summit Vietnam 2022 organized in Hanoi in December 2022, Deputy Minister of Information and Communication of Vietnam directed that “Smart city development is the implementation of digital transformation for an urban area with three main contents including e-government, digital economy, and digital society”. Besides, several scholars in Vietnam are convinced that the development of smart cities in Vietnam is the approach to apply new technology brought into Vietnam from developed countries and at the same time to accomplish the digital transformation and create the database platform in the direction of e-government and e-city.

It is believed that with e-government, the efficiency and transparency of public administration will be achieved. In spite of the fact that e-government and the internet provide many advantages for people to access information, “Viet Nam Provincial Governance and Public Administration Performance Index (PAPI) report” from 2011 to 2021 points to the fact in which the people’s possibility to access and know about the local land use plan is still quite below the average of 50% (Fig. 2). Concerning the e-governance issue, in the 2021 PAPI report, all 63 provinces of Vietnam scored below 4 points on the 1 – 10 point scale. Low results in access to e-government portals and government responses through e-government portals were attributed to the overall poor performance in e-government services. The number of users of the National E-service Portal is very low. The result shows that only 3.53 percent of all 2021 respondents used the National E-service Portal, in which two-thirds of those who used the portal searched for public administrative procedures’ information.

In the Vietnam Urban Sustainability Summit 2022 organized in June 2022 by the Vietnam Government, the report from Vietnam Communist Party’s Central Economic Commission shows that The Provincial Competitiveness Index (PCI) assesses the level of digital transformation based on 3 areas of e-government, digital economy, and digital society, reaching an average score of 0.3 on an absolute scale of 1.0. It contradicts the statistics data in August 2022 from the Ministry of Information and Communication that 22/22 ministries have plan/project of digital transformation for the next 5 years; 60/63 provinces have issued

resolutions/directives/documents of the provincial Communist Party Committees on digital transformation; 62/63 provinces promulgate programs/plans/projects on digital transformation for a 5-year period. Resolution No. 06-NQ/TW of the Politburo of the Central Committee of the Communist Party of Vietnam dated January 24, 2022, on planning, construction, management, and sustainable development of urban areas in Vietnam until 2030, with a vision toward 2045 has stressed: "Speed up the digital transformation in urban management, developing electronic authority towards urban digital authority closely associated with smart urban development". These directions showed that the Government of Vietnam has paid much attention to the development of smart city and considered that is one of the goals to create an urban sustainable system.



**Fig. 2** Percentage of people answered that they were informed and know about the local land-use plan and can access the information [15]

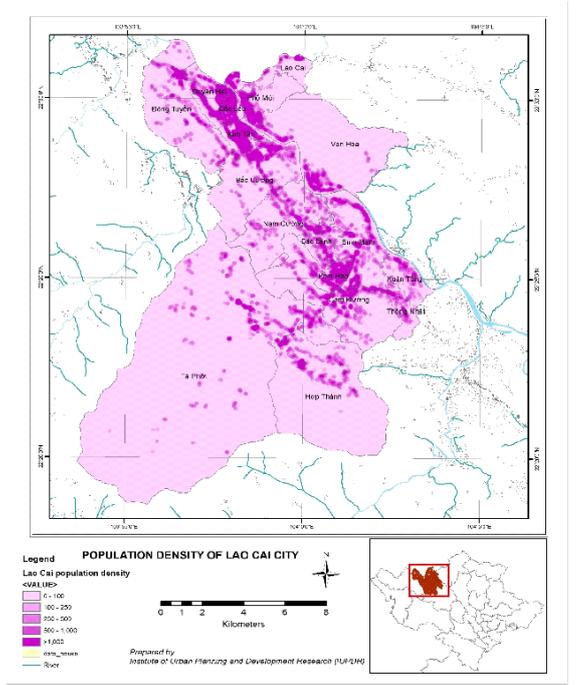
In order to fulfill the task of developing and forming smart cities, the government requires a synchronous and comprehensive digital transformation which must be carried out in all fields, focusing firstly on digital transformation in urban management. However, as mentioned earlier, the level of digital transformation in Vietnam is still less than 33%, so smart cities can be built at the lowest level in which urban governance is carried out with smart tools which are technology solutions to solve situations in urban life intelligently or help municipality's decision-making process. Data sharing and describing each smart component of an IT-based city should be the first steps in urban administration for smart cities. A smart city's objective is to establish an IT-based city with high-quality urban services that are efficiently run and meet the demands of its citizens [16]. Therefore, instead of waiting for a synchronous system to be built in a unified standard, all levels of government in every sector need to share their data for step-by-step management in a smart way. Existing data can be digitalized and transformed into a visible and useable form for other municipal sector leaders. Taking into consideration these approaches, several cities in Vietnam such as Lao Cai and Hue have digitalized and shared data among departments in the form of images in an IT foundation of simple software that enable municipal's leaders and other department experts to use information as supported decision-making tools. Based on the assessment using a set of parameters described earlier, the existing level of flood risk management using a smart urban development approach is taken 2.5 out of 8 points in Hue City and 3.0 out of 8 points in Lao Cai City. In these cities are two disaster vulnerability samples of a small-sized mountainous city (Lao Cai) and medium-sized coastal city (Hue) among 85 cities in Vietnam.

## 5. Urban Flood Risk Management with Digital Transformation: The Case in Lao Cai City of Vietnam

The needs of climate-change-resilience-related sectors in Vietnam are increasingly diversified in the current development. Due to the expanding impact of climate change and natural disasters in Vietnam recently, urban areas become more vulnerable and risks are relatively frequent. Floods are currently the most common natural disaster in Vietnamese urban areas, even in riverside and coastal areas. Floods are a type of natural disaster that causes a lot of damage to the economy, infrastructure, society, and housing in urban areas. In order to respond effectively to climate change, it is necessary to analyze the urban vulnerability and the result should be used as basic data for effective spatial planning, land use planning, and infrastructure planning. In the process of urban development, irrational land use planning together with built-environment changes are considered as one of the causes of urban flooding. Recognizing the vulnerability of cities to natural disasters and disasters, urban governments as well as related agencies have been taking a number of measures to strengthen policies in the areas

of planning, environment, flood prevention, and urban management to reduce urban flooding and to support risk management by improving resilience capability and adaptability to change climate as well as other natural disasters. Interventions include carrying out disaster risk assessments for urban areas, developing urban disaster risk management strategies, preparing land use planning, especially for regions with disaster risk, regulating built standards and adaptive design for climate change resilience as well as disaster risk resilience. Awareness of disaster risk management should be raised at all three stages: (1) Prevention: Preparation activities to be carried out before the occurrence of disasters; (2) Response: Activities carried out during natural disasters including relief work; and (3) Recovery: Remedial actions taken after the occurrence of disasters.

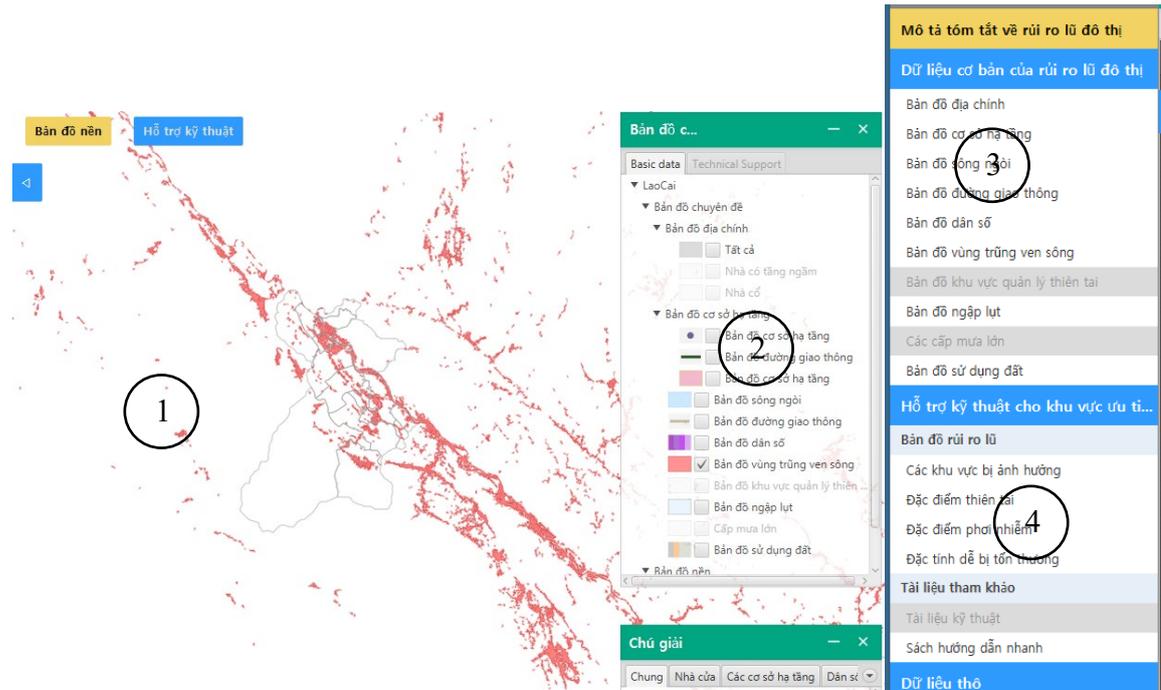
Research in Vietnam shows that there is a need for strategies to reduce the vulnerability of cities, in which the provision of support systems for flood prevention, or the adaptability of households by using a flood control support system prior to construction could be one solution. Surveys carried out by the government in Vietnam show that the available data in cities is scattered in different departments. This data system has not been unified and transformed on one platform so that it can be shared. Another critical problem is that these data can be only used and displayed on professional software and this makes things difficult for urban leaders to have support from professionals or experts to be able to refer information for decision-making (Fig. 3). As many scholars agreed with the conditions of Vietnam, it is necessary to exploit the available data and apply the technology imported from developed countries in parallel with the data digitalization process. One of the proposed options is to build a basic data management system to develop an urban flooding support system in Vietnam and apply it as a pilot in Hue city and Lao Cai city.



**Fig. 3** Digital elevation model (DEM) on population density and Low land area in Lao Cai prepared by ArcGIS [17]

The objective of these approaches is to develop a database management framework on the basis of existing data systems in cities and to develop an urban-flood-control-support-system in the process of making planning decisions. The basic objectives are: (1) Develop a basic data management framework for urban flood analysis in Vietnam and thereby (2) Create an urban flood risk information profile and develop a visual information system based on information technology application to control urban flooding. The long-term goal is to develop and disseminate support technology for decisions on urban flood prevention measures to assist those who need update-visualized and simplified data on urban flooding and disaster prevention, such as Vietnamese government officials, urban planners, and citizens and the data can be easily accessed through the internet. The idea of these approaches is to use available data systems, digitize and display them in the form of visual images so that leaders, professionals, or people can refer to them for updated information on topography, spatial planning, river network, rainfall, population, disaster prevention works as well as vulnerable structures in the area. The software is based on the core software developed by the Korea Research Institute for Human Settlements (KRIHS) and is free-of-charge transferred to Vietnam. This software has been successfully used in Korea. The information displayed is

intuitive and does not require the use of professional software such as ArcGIS or ArcMAP. This is an indirect way of creating a common platform for data sharing and shared data digitization.

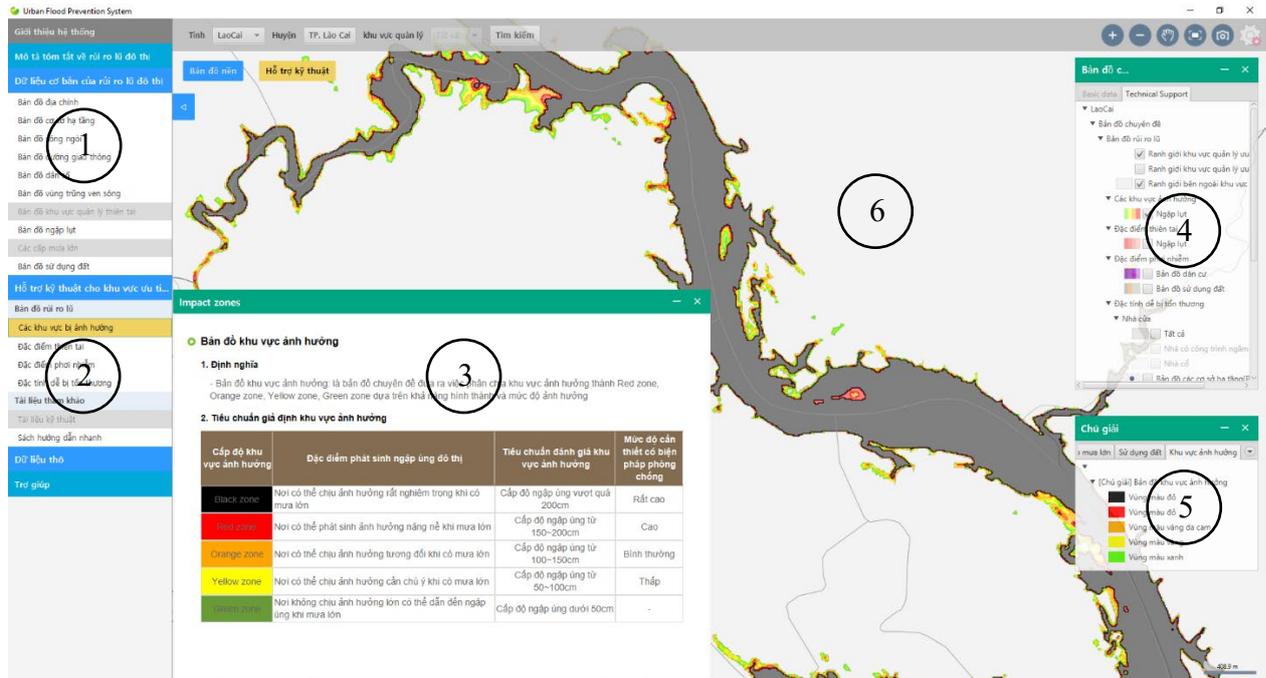


Legends:

1. Main display area
2. Data layer selection to be displayed
3. Type of map selection
4. Selection of technical information to be displayed

**Fig. 4** Digital elevation model (DEM) on population density and Low land area in Lao Cai prepared by ArcGIS [17]

The data system that needs to be collected will be a very important basis for analyzing the flood situation and status in urban areas. Data systems need to be provided by multiple agencies and require cross-sectoral coordination. These include topographic, spatial, and precipitation data, topographic data such as DEM (digital elevation model), land use plans and river network maps, and digitized spatial data on population, roads and disaster prevention works, and rainfall data over the years. The more detailed and complete these data are over a period of 15 to 20 years or more, the more effective the system will be. The work of converting all data into the same format so that it can be easily displayed visually is an effective approach. Updating the database will be based on the data from the relevant agencies in the same format will be very easy and flexible. The rain, topography, and spatial data of Hue and Lao Cai cities were collected and processed, in which, DEM (digitized elevation model) data were collected and processed on the basis of maps of 1:10,000 scale including topographic maps, land cover, land use, rivers, transportation, infrastructure... In addition, the DEM map also integrates information about population, damage, and disaster prevention infrastructure. The DEM map is updated on the basis of rain data from stations in the area as well as data on cross-sections of the rivers and river profile.



Legends:

1. Type of map selection
2. Selection of technical information to be displayed
3. Detailed information of the selection area
4. Technical support selections
5. Legends of different layers
6. Main display area

**Fig. 5** Technical support for spatial plan decision making in the urban flood prevention system [17]

Based on the collected DEM data, flood risk data and a display framework on the software have been built and designed. The displayed data is managed on the basis of (1) urban flood risk data profile and (2) displayed format regulation of urban flood risk. 73.2% of comments from the staff members of the Department of Construction, the City People’s Committee Office, and the Planning Institute for the information support software are very positive because it is easy to use and intuitive.

Based on the set of parameters in Table 1 to assess the level of flood risk management using urban-flood-control-support-system software, the result of the level of smart urban development in connection with flood risk management in Lao Cai city is shown in the Table 2.

**Table 2** Level of flood risk management using urban-flood-control-support-system software in Lao Cai city

Parameters criteria	Low (poor) 0	Medium (average) 0.5	High (good) 1
Co-operation	Low and ineffective co-operation in flood risk management	Moderate and sufficient effective of co-operation in flood risk management	More than adequate and stable level of co-operation in flood risk management
Leadership	Low and ineffective leadership in support of risk management using smart development approach	Moderate and not always effective level of leadership in support of risk management using smart development approach	Clear and effective leadership in support of risk management using smart development approach
Participation	Low level of participation and limited actors participate	Adequate actors participate and level of participation is consult	Most of actors participate and level of participation is co-production

Parameters criteria	Low (poor) 0	Medium (average) 0.5	High (good) 1
Communication	Limited communication channels with the related bodies are established	Sufficient communication channels with the related bodies are established	Adequate communication channels with the related bodies are established
Data exchange and open data platform	Data resources are available but the exchange is limited	Data resources are available, most of them are exchanged and opened partially	Data resources are available and most of them are exchanged and opened
Service and application integration	Some services and application have been integrated with limited satisfaction from users	Major services and application have been integrated with sufficient satisfaction from users	Most services and application have been integrated with more than adequate satisfaction from users
Accountability	Limited responsibility for the actions in support of risk management using smart development approach	Moderate morale of responsibility for the actions in support of risk management using smart development approach	High morale of responsibility for the actions in support of risk management using smart development approach
Transparency	Limited level of transparency in procedures and information exchange	Sufficient level of transparency in procedures and information exchange	Clear procedures and more than adequate level of information exchange

The result shows that the level of smart urban development management has increased to 6 out of 8 points compared to 3 points in the previous stage. It shows the positive and effective impact on the decision-making process of city leaders in relation to flood risk and disaster vulnerability areas as it provides visualized and simplified information. Nevertheless, this approach and this software are not fully optimized when the accountability and transparency parameters just are at a medium level. Besides, not all services have been integrated so that all actors, stakeholders, and community can access the data and application.

The software and this approach of flood risk management received high recommendations from staff members of the Department of Construction, the City People's Committee Office, and the Planning Institute. However, most of them suggest that training is needed so that many people can use the software. Moreover, local related departments should actively provide detailed data so that the software can be more effective. This approach shows that instead of waiting for a synchronous system to be built in a unified standard from the central government to the local, all departments of local government in every sector can share their data in a smart way and that will help municipal leaders in the development-related decision-making process.

## 6. Conclusion

Smart cities can combat climate change as cities invest in the Internet of Things to help monitor and manage the flow of traffic or to develop smart infrastructure to reduce CO<sub>2</sub> emissions. But for disaster mitigation and preparation for climate change resilience, smart governance, digitization, and technology can provide shared data for the development orientation. Although the task of the public administration is fighting against climate change, it needs the participation of all the stakeholders. In addition, the impact of technological trends also helps. Co-operation and participation among stakeholders in providing and sharing information can create a foundation for a smart city. Urban management for smart cities needs to start with sharing data and existing data can be digitized and transformed into a visible and easily accessible form for municipal leaders' decision-making process. The case of Lao Cai city – Vietnam shows that instead of waiting for a synchronous system to be built in a unified standard from the central government to the local, all departments of local government in every sector can share their data in a smart way and that will help. The idea of this approach is to use available data systems, digitize and display them in the form of visual images so that leaders, professionals, or people can refer to them for updated information on topography, spatial planning, river network, rainfall, population, disaster prevention works as well as vulnerable structures in the area. To ensure success, it needs to start with co-operation and participation.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors confirm contributions to the paper as follows: **study conception and design:** H.V. Ngo; **data collection:** Hau Do; **analysis and interpretation of results:** H.V. Ngo, Hau Do; **draft manuscript preparation:** H.V. Ngo. All authors reviewed the results and approved the final version of the manuscript.*

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